Tecnews

A publication for the presentation of new ideas . . . new methods . . . new products . . . in the associated fields of radio and electronics.

ELVIN W6TT
MARIO W6DUB

PUBLISHED MONTHLY BY THE ELMAR ELECTRONIC SUPPLY CORPORATION
(FORMERLY ELECTRIC SUPPLY CO.)

FEB. - MAR. 1955

140 11th ST. OAKLAND 7, CALIF.

IF IT WON'T MATCH . . . TO "L" WITH IT !!!

By Clayton F. Bane W6WB

Let it be said at the outset that the "L" network is one of the most flexible and adaptable of the entire RF impedance matching network series. In its favor is the fact that the L network will have lower losses in a particular application than will the much more familar "pi" type. For these and other reasons, the subject has been deemed of sufficient importance to warrant a full-length presentation. To this end, the bosses Elvin and Mario have relinquished their interior ad page so that the writer could present all possible information in the space available. Now to the subject proper.

The "L" network looks symbolically like an inverted letter "L" and includes two reactive elements, one in the series arm, the other in the parallel arm. See Fig.1.

It is important to note that the network arms are specified in terms of reactance rather than in inductance and capacity. This makes possible network design formulas that are independent of frequency. A given network with a certain impedance transforming ratio can therefore be operated at any frequency by converting the inductive and capacitive reactances into their equivalent L and C values.

HOW IT OPERATES: L networks depend for their operation upon a well-known electrical rule, namely: that each combination of a resistance and reactance in parallel has an exact equivalent consisting of a resistance and reactance in series. This rule is applied practically in the following manner: Two resistance, (impedances) are always known, the load you have and the load that is to be matched. Obviously, one of these resistance is always higher than the other. The two known resistances are utilized in a formula to determine the value of reactance which must be placed in parallel with the highest of the two so that the equivalent series circuit contains the lowest resistance term. A second simple formula gives the required value of reactance for the equivalent series circuit. The design parameters of L networks are such that operation is on an "all or nothing basis". That is, the assumption is made that the generator, (a vacuum tube for example) is to work into a load equal to its own resistance. Under these conditions maximum power transfer, (full coupling) will result when the network is properly tuned. Coupling can be controlled with a pi network but not with an L.

While it is possible to achieve an exact impedance match, (at one frequency) with the L network, the out put will never be a pure resistance if reactances in both parallel and series arms have the same sign. (i.e. are both inductors or capacitors.) In practice the network is made resistive by using an inductor in one arm, a capacitor in the other.

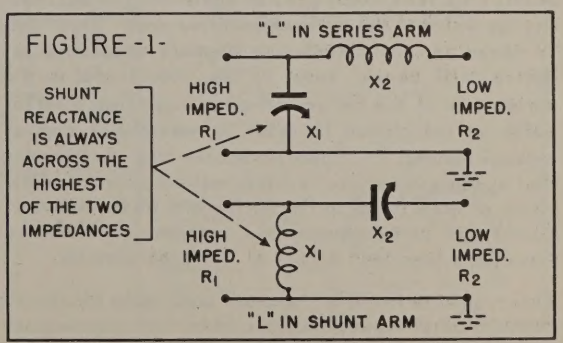
Since it is the purpose of this paper to provide information that can be applied quickly and practically, mathematical manipulation has not been given. The accompanying charts should be adequate for the great majority of amateur applications where L networks can be utilized. Basic formulas are given for those who prefer to "Roll their own". The formulas do show certain important information however which is interpreted for the non-mathematical reader as follows:

(1)- The parallel reactance always connects across the higher of the two impedances involved.

(2)- The value of this shunting reactance, (1) depends upon the arithmatical value of the impedance across which it is connected. This is to say that, regardless of the impedance ratios involved in the network, when

(Continued on inside page)

FIGURE -1-



(Continued from front page)

the impedance is high, the value of X will be greater than when the impedance is low. Since the shunting reactance will be a capacitor in most cases, it is important to observe that the lower the reactance, the larger the capacity. Take for example, two networks each with a 10:1 impedance ratio: "A" matches 1000 to 100 ohms, "B" matches 100 to 10 ohms. The formula shows that the necessary shunting reactance for "A" will be substantially higher than that required for "B". In terms of capacity, "A" shunting capacitor will be much smaller than the capacitor in "B".

(3)- The "L" network is a two-way device . . . it may be used to transform impedances up or down, provided only that (1) is observed. Practically, a 10 ohm beam may be matched to a 50 ohm line or a 50 ohm line to a 1500 ohm antenna base impedance.

ADVANTAGES. . .USES: L networks can be designed to match virtually any two differing impedances. While not strictly pertinent to this discussion, it should be stated that whether or not a network, (L or otherwise) is used in a particular circuit will depend to a great extend upon the loss present under the existing mismatched condition. To clarify, both pi and L networks utilize inductors, even the best of which must have some loss. It follows then that if the gain due to perfect match is a matter of a fraction of a db, there would seem to be little point in using a network that might, (due to inductor losses) introduce an equivalent or even greater loss.

The L network does offer distinct advantages in many applications where the loads to be matched are not pure resistances but contain a small reactive term. (For example, a ground plane antenna that is not exactly resonant at the desired operating frequency.) In such cases, the L can affect an exact impedance match and bring the VSWR on the line to unity by cancelling out the reactance existing at the antenna feed point. This is accomplished by increasing or decreasing the value of the network reactive arms. Practically speaking, an antenna that appears capacitive reactive will cancel some of the inductance in the series arm of the network thereby requiring a larger value of inductance in order to reestablish correct network tuning. The opposite is also true. An antenna that appears inductive reactive will require a smaller value of inductance in the series arm of the network. All things being equal, an L network will always have less loss than a "pi" or "T" type network.

This type of network is therefore preferable for all impedance matching applications other than from vacuum tube to load. It is undesirable in the latter application since full power is always drawn from the tube.

L networks are of particular advantage where multiband operation of a single vertical antenna is contemplated. An exact match, (at a single frequency) to a 52 ohm coax line can be achieved regardless of whether the antenna base impedance is higher or lower than that of the coax line.

LIMITATIONS: There are certain sets of operating conditions, (particularly evident on the HF bands, i.e., 10, 6, 2 meters) where an L network is impractical in the sense that the necessary values of reactance cannot be achieved. In this regard, the inductance is generally the troublesome element since in some instances it may become vanishingly small. A typical example: Match a 10 ohm beam to a 50 ohm line at 10 meters. The calculations show the parallel capacitor to be 227 micromicrofarads, the inductance to be .11 microhenries. If this low value of inductance is to be obtained at all it will probably be in the form of a hairpin rather than of a conventional multi-turn coil. Another consideration, is that the leads necessary to connect the network to the driven element of the beam may, in themselves, have more than the required inductance. Since it is normally considered advisable to provide balanced feed to a beam, the network should operate in conjunction with a balun and should therefore be a balanced, rather than a one-side grounded type. This means that one-half of the total calculated inductance must appear in each series arm, twice the calculated capacity in each shunt arm with the mid-point connected to ground. The absurdity of attempting to make an already too-small inductor smaller yet is quite apparent.

TUNING AN "L" NETWORK: Since these networks are virtually always operated in conjunction with a transmission line, proof of proper network tuning can be best determined by checking the standing wave ratio on the line. As stated, an L network can achieve a perfect match, (unity standing wave ratio) at a given frequency, assuming that the network constants can compensate for reactance present in the load. An L network cannot be tuned by observing amplifier loading as the network constants are changed!

Note that both L and C must be varied in order to establish correct network tuning. In practice, an arbitrary setting of L and C will yield some value of SWR. L should then be changed and C rotated through its range watching the SWR for a downward trend. Ultimately, the inductance value will be such that the SWR will drop to unity at some capacitor setting.

MARIO
W6DUB

(This assumes that the capacitor has a sufficient maximum value.) Reactance present in the load may cause both inductance and capacity to vary markedly from values determined by formula. In summary, don't try to tune an L network by amplifier loading or by "S" meter reading where the network is to match a line to the receiver input. Use a standing wave bridge and a low-power source of bridge excitation. A fraction of a watt won't hurt the RF coils in your receiver. In the latter case, do make certain that your SWR is always brought to its lowest value by adjustment of the RF antenna trimmer since the receiver input should present a resistive load to the network.

In applications where the network is called upon to match a line to the driven element of a paristic beam, consideration must be given to the possibility that the network will be seeing both resistance and reactance. Unity SWR can still be achieved but the network constants will depart from those determined by formula. L and C can become larger or smaller than the design values depending upon the magnitude and sign of the reactance present in the driven element of the beam antenna.

In one practical instance, a calculated and subsequently measured 5 turn series inductor required 7 turns to produce unity SWR when installed in the network to match a 52 ohm line to the driven element of a 3 element 20 meter beam. The shunting variable capacitor also required some readjustment. It is thus apparent that both L and C should have plus or minus adjustment leeway in all cases where a line is to be matched to an antenna by a L network.

Analysis of network branch currents indicates that the current through the series reactance will be higher than that through the parallel reactance. The difference is fairly marked at low impedance ratios, less so at high ratios. Network losses for certain impedance ratios can therefore be decreased somewhat by using an inductor in the parallel arm, a capacitor in the series arm. At high impedance ratios, X_L and X_C are virtually equal, i.e. the combination is near resonance. L can therefore be determined readily by conventional grid dip methods when C is known.

R_1	R_2	X_1	X_2	X_1= C	X_2= L	freq.
50	10	25	20	454	.229	14
50	20	38.8	24.6	292	.28	14
100	50	100	50	113.5	.526	14
200	50	116	86.7	97.9	.975	14
300	50	134.4	113	84.5	1.28	14
400	50	151.6	132.5	75	1.5	14
500	50	167	150	67.5	1.71	14
600	50	180	166	63	1.88	14
700	50	193.2	181	58.8	2.06	14
800	50	204.8	194	55	2.2	14
900	50	216.9	206	52.4	2.32	14
1000	50	228	218	49.8	2.55	14
1500	50	277.5	270	41	3.06	14
2000	50	316	313	36	3.59	14
2500	50	352.5	351	32	4.09	14

R=OHMS, X=OHMS, C=μμf, L=μh, f=MEGACYCLES

for 3.5mcs=multiply L and C by 4
for 7mcs=multiply L and C by 2
for 21 mcs=divide L and C by 1.5
for 28 mcs=divide L and C by 2

FORMULAS

$$X_1 = \sqrt{\frac{R_1^2 \times R_2}{R_1 - R_2}}$$

$$X_2 = \sqrt{R_1 \times R_2 - R_1^2}$$

$$C\mu\mu f = \frac{1{,}000{,}000}{6.28 \times f_{mc} \times X_{ohms}}$$

$$L\mu h = \frac{X_{ohms}}{6.28 \times f_{mcs}}$$

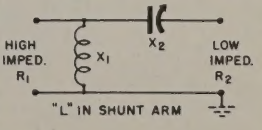
R_1 = highest of the two impedances

R_2 = lowest of the two impedances

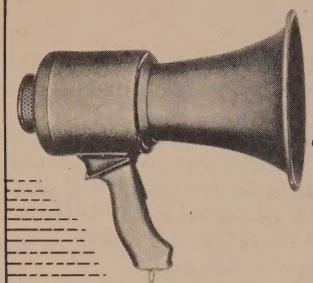
X_1 = reactance of shunt arm

X_2 = reactance of series arm

SHUNT REACTANCE IS ALWAYS ACROSS THE HIGHEST OF THE TWO IMPEDANCES



ELMAR stocks Complete equipment for CD

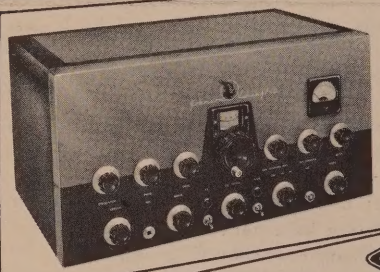


Audio Hailer

SIZE: 13-3/4" long, Bell diam. 8-1/4".
WEIGHT: 5-1/2 pounds
AUDIO OUTPUT: 3 watts. (measured at speaker.)
ACOUSTIC OUTPUT: 112 db, (measured at 5 feet.)
BATTERIES: 3-No.935"A", 3-No.457"B", 1-No.411"C".
BATTERY LIFE: 5000 - 10 second messages.
AMPLIFIER: 3 stage push-pull.

Net 99.00

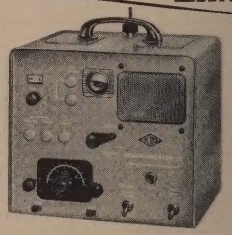
JOHNSON VIKING - FOR C-D



Net 398.00

A deluxe version of the well known Viking 11, the Viking 11-CD transmitter features push-to-talk operation, modulation limiting and extended frequency coverage for Civil Defense.
This transmitter has been approved for C-D use as listed in Issue No.1 "Certified Radio Equipment" and qualifies for the matching funds program. Contact Elmar

GONSET COMMUNICATOR



The complete VHF station in a conveniently portable form. Built in dual power supply for 6V DC or 115 AC. Xtl controlled transmitter, (VFO available). Tunable receiver covers 144 to 148.3 for C-D and CAP applications. Has "Cascode", RF, three stages I.F., famous Gonset noise limiter and squelch, (deluxe models only). Audio stages arranged for use as emergency public address system.

Standard - Net 209.50 Deluxe - Net 229.50

Also...
COLLINS
NATIONAL
HALLICRAFTERS
RECEIVERS
suitable for C-D service.

Produced by C. F. Bane Advertising

Copyright 1950 by Electric Supply Co.

Elmar ELECTRONIC SUPPLY CORPORATION
(FORMERLY ELECTRIC SUPPLY CO.)
140 - 11TH STREET,
OAKLAND 7, CALIFORNIA

Sec. 34.66 P. L. & R.
U. S. POSTAGE
PAID
PERMIT NO. 759
OAKLAND, CALIF.

ANDREW H. ELSNER W6ENV
4539 BECK AVE.
NO. HOLLYWOOD, CALIF.

FORM 3547 REQUESTED